The Earth System Science Education Alliance Program

Robert J. Myers, Ph.D.
NASA Classroom of the Future

bmyers@cotf.edu; phone (304) 243-2368, fax (304) 243-2497

STUDENT ACHIEVEMENT AND TEACHER PREPARATION

There are favorable indicators concerning math and science education in our schools as reported in *The Learning Curve* (NSF, 1996). According to this report elementary schools in the United States are devoting more time to mathematics and science instruction. More college degrees are being awarded in the natural sciences and engineering, and many gains have been made by minorities in math and science achievement.

There are still many areas needing attention, however. In 1991, American 13-year olds were outperformed on an international science assessment by students in Hungary, Korea, Taiwan, and Switzerland (National Education Goals Panel, 1995). Teacher preparation still remains weak, with close to one-third of elementary teachers never having taken a three-credit hour course in biological, physical, or the earth systems sciences. In fact, less than 30 percent of elementary school teachers say they feel well qualified to teach life science (NSF, 1996). Research also suggests that students in science classes engage in tasks with low cognitive demand--emphasizing the memorization of facts and algorithms without understanding why the algorithms work (Tobin & Gallagher, 1987).

The role of the teacher is changing dramatically as we move toward the twenty-first century. A consensus of educators view teachers as key components in the development and implementation of any curricular reform. Teachers must be well-prepared for the critical role they will play, particularly if schools are to continuously improve and adopt strategies associated with inquiry and information-centered technology. The tradition of "teaching the way I was taught in graduate school" may be a notion of the past as educators poise for the continuous renewal and invigoration of their classroom methodologies in light of new, upcoming technologies.

Various organizations (the NRC, 1996; AAAS, 1993; BSCS, 1995; and the NSTA, 1992) have suggested that systemic change in classrooms may be achieved through the development of new standards. The new standards all emphasize student-centered classrooms, problem solving, critical thinking, the promotion of skills for life-long learning, collaborative learning, teachers as mentors, and the use of technology in the classroom. Reforming education will require substantive changes in how math and science are taught, which in turn will require equally substantive changes in professional development practices at all levels. On-line courses consisting of communities of learners are experiencing increasing use and credibility. This paper outlines the design, development and implementation of a middle school teachers' earth systems science graduate course. This 16-week course was developed at the Center for Educational Technologies, Wheeling Jesuit University, under the sponsorship of the National Aeronautics and Space Administration's Mission to Planet Earth. The themes of earth system science content and collaborative, inquiry-based science education prevailed within an electronic environment where teacher participants took responsibility for their learning within a structure of clear expectations.

Under a cooperative agreement with NASA's Earth Science Enterprise, the NASA Classroom of the Future (COTF) began developing online graduate courses for teachers at the K-4, middle school, and high school levels. The goals of the program were to (1) allow teachers to learn Earth System Science

(2) provide external resources from NASA and other governmental agencies, (3) increase teachers confidence in use of technology, (4) provide teachers with more classroom activities, and (5) model new teaching practices through design of the online courses. In the sections that follow, the design and delivery of the middle school course is discussed, followed by introduction of a NASA program to disseminate the online courses to colleges and universities engaged in teacher inservice.

WEB COURSE DESIGN

The course was delivered through the World Wide Web (WWW) and featured collaborative exercises and threaded discussion. This on-line asynchronous environment was chosen to accommodate teachers in remote locations and those whose schedules did not provide for on-campus attendance. Participants were chosen for the course based on access to the WWW and their stated interest in helping refine the course for future iterations. The course also addressed the US National Research Council's standard for using inquiry-based approaches in science teaching. This was accomplished by modeling a collaborative, student-centered environment in which teachers relied on each other to develop knowledge.

A primary concern during course design was to create an on-line learning environment where interdependence among participants provided the necessary glue for a successful community of learners. Davis's (1997) recipe for building a self-sustaining community included shared goals, challenges that cause relationships to form through exchanges of ideas, regular reflection for developing shared understanding, and an infrastructure or set of places that defined the way for the virtual community to form and interact. One means of following this recipe is to have participants focus on independent information collection, then enter "virtual space" to test ideas and ask questions of each other and the mentors. Rogers and Laws [2] addressed the challenge of building a community through extensive on-line discussions and providing opportunities for cooperative learning to support participation.

Cooperative learning is a successful teaching strategy in which small teams use a variety of learning activities to improve their understanding of a subject. Each team member is responsible not only for learning but also for helping others. This paradigm rejects the idea of competition in the classroom and promotes teamwork among learners by defining a variety of roles and by setting shared goals. It is important for each team member to take responsibility for the progress of the whole group -- sharing ideas, materials and resources -- and sharing equally in the rewards of a successfully completed assignment. A variant of cooperative learning is the jigsaw method in which participants are sent to new teams where each individual becomes an "expert" in a certain area. These experts then return to their original teams where information is shared with other team members in creating a product, in this case, an earth systems diagram.

DEVELOPMENT TEAM AND PARTICIPANTS

The development team included instructional designers, earth systems scientists, a graphic designer, and a web master. The inclusion of an expert in on-line collaborative environments and the web master proved to be crucial in the design and implementation. Two sections of participants (teachers) enrolled in the course (N=44). Each section had two mentors, a master teacher and an earth systems scientist. The mentors guided discussions by interjecting when necessary, responding to weekly discussions, and replying to students' journal entries.

Participants came from across the United States and had diverse backgrounds in earth systems science and on-line experience. All except two were practicing teachers; of the two, one is returning to the classroom; the other is a curriculum specialist.

IMPLEMENTATION

The on-line environment was seen as a place for collaboration and knowledge building, not as a repository for earth systems content. With this view in mind, participants were mailed necessary background reading materials, CD-ROMS, and other supporting materials. The on-line site was limited to week by week instructions, information about grading, how to thrive in on-line communities, and the discussion area itself.

Design of the first three weeks allowed participants to become acclimated before plunging fully into collaborative activities. During this time most discussion occurred in "Course Space" (Figure 1). Starting slowly had several advantages. It allowed non-technical users to learn about cyberspace and for everyone to become accustomed to the site. During weeks two and three participants learned about the others assigned to their teams, and they were introduced to earth systems science.

During week two, the 1988 Yellowstone National Park fires were used as an event that impacted upon earth's interacting and interdependent spheres (i.e., atmosphere, biosphere, hydrosphere, and lithosphere.) Using a graphic depiction, participating teachers were presented with a tutorial on how to examine positive and negative feedback loops and dynamic equilibrium. During week three participants worked within their teams in designing a new earth systems diagram. The meteorite impact on the Yucatan Peninsula was used as the earth event for this diagram. Participants also reflected on their progress in content knowledge and posed questions in the "Journal Space." This was a weekly requirement and served as a space in which one-on-one discussions could be made with the course mentors.

Week four signaled the start of what would be four, three-week series, during which time deforestation, volcanoes, sea ice change, and hurricanes provided the events for group discussion and earth system diagram construction. This paper elaborates on the first, three- week series. To begin the deforestation discussion, each section of approximately 20 participants was broken into new "Sphere Space" teams.

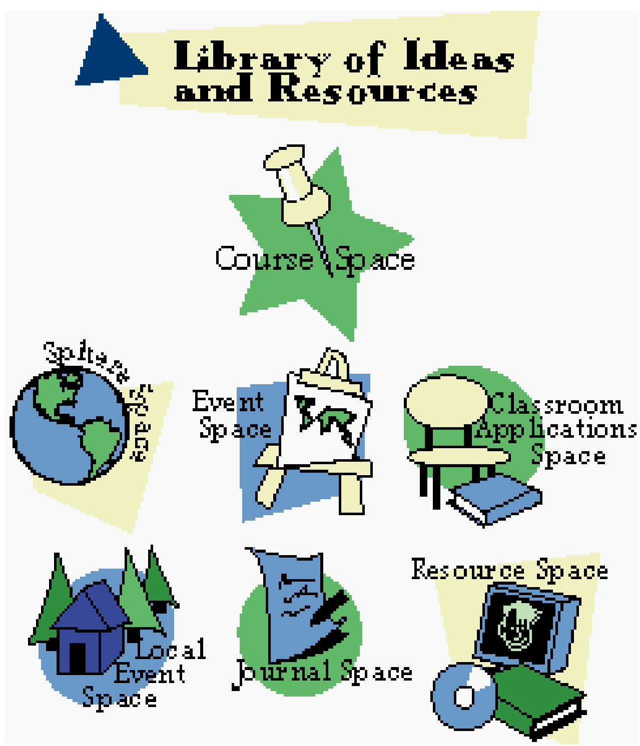

Fig. 1, Collaboration Space

This meant, for example, that in a group of four, one person went to the atmosphere sphere group discussion, one to the biosphere group discussion, and so on. The objective of the sphere group discussion was for each member to become as knowledgeable as possible about deforestation's impact on his or her sphere. At the end of the week, each participant had collected and discussed information concerning his or her sphere and then returned to the cooperative team to help with the construction of the earth systems diagram.

During week five the original cooperative teams reformed and work began on the earth systems diagram. This work was completed in "Event Space" (see Figure 1). Each member was counted on for knowledge developed during the previous week's sphere group discussion. Mentors watched the discussion, intervening only to ask thought-provoking questions or respond to requests. Week six provided teacher participants opportunities to think about and share classroom activities they would use with their middle school students. This information was recorded in "Classrooms Applications Space."

REQUIREMENTS AND EVALUATION

Course developers provided participants rubrics as guides for course expectations and grading purposes. Participants were graded on their contributions to Sphere Space, Event Space, and Classroom Activities. Points were also awarded for journal entries and for the final project. For the final, participants could develop an earth systems diagram based on theories about geoengineering, or they could submit an article to Science Activities magazine.

RECOMMENDATIONS

Who succeeded in this course? Based on the low drop out rate (5 of 44), and the end-of-course surveys from participants, most succeeded. One participant noted in an email that she hoped the course would never end. Some individuals dominated discussion and some shied away, remaining aloof and laconic, much like face-to-face discussions would be. Rogers and Laws [6] suggest that students who succeed in asynchronous, distance learning courses tend to be more self-disciplined learners. McClure [7], in discussing development of the WELL, said developers thought the best participants would be intelligent people with diverse backgrounds and who were sufficiently outgoing and extroverted. The jigsaw design with well-defined spaces for public, private, large and small group activities was designed to mitigate against an "extroverts only" environment.

The course was extremely rigorous and time-consuming for teacher and mentors alike. It was designed to be this way, yet many teachers had not anticipated the heavy workload. Five quit. Two or three were talked into continuing through intervention by mentors or course developers. This is similar to the negotiations likely to ensue in on-campus, face-to face courses.

Having a master teacher and an earth system scientist was a luxury that not many universities could afford. If this becomes too problematic, course developers could elect to spread the scientist's workload over multiple sections. A frequently asked questions (FAQ) area could also be developed to tap their content expertise.

Even with two mentors per approximately 20 students, the mentors' workload was huge. Developers would do well to keep the number of students in these classes at no more than 24. Based on what was observed in this course, raising the number of students is likely to detract from students' learning.

Developers envisioned all course coordination, communications, and discussions happening in asynchronous, virtual space. This proved to be overly optimistic; many phone calls and emails were used to provide scaffolding and support. One team of teachers formed their own synchronous, online chat sessions in order to facilitate timely construction of their earth system diagram. It is likely that in order to overcome the gap created in distance education, multiple means are not only likely, but necessary.

The groupware used for this course did not allow the participants to display graphics, pictures, or images, unless the web master assisted. The cooperative team mentioned above put their systems diagram on their own web site.

The web master's role was essential. The groupware used for the course needed a great deal of tweaking early in the course and he was called upon time after time to address users' technical problems. Many of these problems resulted from incompatibilities between browsers, versions of the browsers, and differences in users' platforms (Macintosh or Windows).

Giving teachers weekly tasks and deadlines paid off, especially in this asynchronous environment. The best weekly time frame was Monday morning through Sunday night; teachers liked to have the whole weekend to complete assignments.

SUMMARY

An overriding objective in the development of this on-line course was to create "reasons" for individuals to engage in the material. The population consisted of very busy classroom teachers. Course developers purposely designed the structure to be student-centered so that participants relied on each other for input. As discussed above, this was accomplished through the jigsaw strategies that made participants depend on each other for essential information in creating the earth systems diagrams. There is always room for improvement and fine tuning, but developers have been pleased with the implementation of this course. After minor tuning, it will soon be offered again and will provide a model for development of other on-line courses.

THE ESSEA PROGRAM

The COTF has developed and implemented online courses at the K-4, middle school, and high school levels. In an effort to disseminate these courses to have an impact on earth system science learning in the K-12 arena, the Earth System Science Education Alliance has been sponsored by the Earth Science Enterprise.

Universities, colleges, science institutions, and environmental education organizations involved in teacher pre-service, as well as in-service professional development, have been offered the opportunity to participate in this program (see http://www.cet.edu/essea). For example, we envision that groups such as the NASA Space Grant Consortium, the ESSE Program, the US Global Change State Education Teams, the NASA Minority University Space Information Network (MU-SPIN) Program, and other institutions involved in higher education, professional development, Earth System Science, and distance learning could all be potential providers of the K-12 Earth System Science on line courses for teachers.

It is the intent of the CET-IGES team to involve 22 training teams over a five-year period. Therefore, the program will commence during calendar year 1999 and continue through 2004. Participating institutions will be required to commit to a three-year period. During the first year they will receive support while learning the system. During the second year they will integrate the courses onto their host computers and then become independent, autonomous users in the third year. Because the entire program is five years in duration, new participating institutions can start in years two and three and still have time to finish within the five-year period. The extended time frame provides the CET and IGES an opportunity to improve the courses and program implementation through formative evaluation, to capture the very best of the program and display it on a central web site, and to increase program dissemination and participation to a wider audience.

IMPLEMENTATION

The objectives of this proposed program are to:

- promote on line professional development courses that will produce knowledgeable and well-equipped K-12 Earth System Science teachers;
- demonstrate the effectiveness of the World Wide Web in the promotion of a national professional development program for K-12 Earth System Science educators; and
- directly respond to the need to prepare more teachers to meet the demand of a growing US student population

This innovative program, with the NASA on line Earth System Science courses as its centerpiece, will not only include training teachers, but will also develop an active and long-term mechanism for delivering professional development on a national scale.

The general plan for developing this long-term mechanism for national delivery of the on line Earth System Science courses is to enlist the participation of universities, training organizations, and other institutions affiliated with professional development. These organizations would respond to an IGES-released solicitation requesting participation in this alliance.

The organizations would propose to:

- take part in this long-term educational project;
- recruit teachers to take the on line courses;
- provide the on line course(s) to teachers;
- agree to participate in training in order to provide the on line courses;
- commit to providing the technical capability to implement the courses; and
- provide feedback and evaluation information to the ESSEA team.

In the event that MU-SPIN organizations do not propose under the ESSEA program, organizations can still apply to participate by getting copies of the source code from the NASA COTF. Contact Dr. James Botti (jbotti@cet.edu) or Dr. Bob Myers (bmyers@cet.edu) for details.

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